4-22-74

REPORT NO. NADC-74058-30

PROGRAM PLAN FOR INVESTIGATION OF MODEL E-1/C-1 AIRPLANE CATAPULT AND HOLD-BACK OPERATIONS CAPACITY

Louis Berman
Air Vehicle Technology Department
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

25 March 1974

Program Plan Report
AIRTASK NO. A5105103/001-4/251000002
Work Unit No. KG101

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

Prepared for
NAVAL AIR SYSTEMS COMMAND
Department of the Navy
Washington, D. C. 20360

NOTICES

REPORT NUMBERING SYSTEM - The numbering of technical project reports issued by the Naval Air Development Center is arranged for specific identification purposes. Each number consists of the Center acronym, the calendar year in which the number was assigned, the sequence number of the report within the specific calendar year, and the official 2-digit correspondence code of the Command Office or the Functional Department responsible for the report. For example: Report No. NADC-73015-40 indicates the fifteenth Center report for the year 1973, and prepared by the Crew Systems Department. The numerical codes are as follows:

CODE	OFFICE OR DEPARTMENT
00	Commander, Naval Air Development Center
01	Technical Director, Naval Air Development Center
02	Program and Fiscal Management Department
03	Anti-Submarine Warfare Program Office
04	Remote Sensors Program Office
05	Ship and Air Systems Integration Program Office
10	Naval Air Facility, Warminster
20	Aero Electronic Technology Department
30	Air Vehicle Technology Department
40	Crew Systems Department
50	Systems Analysis and Engineering Department
81	Administration and Technical Services Department
85	Computer Services Department

APPROVED BY: TMead DATE: 25 March 1974

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NADC-74058-30	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Program Plan for Investigation of Model E-1/C-1 Airplane Catapult and Hold-Back Operations Capacity		5. TYPE OF REPORT & PERIOD COVERED Program Plan 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Louis Berman		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Vehicle Technology Department (Code 30) Naval Air Development Center Warminster, Pa. 18974		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AIRTASK A510-5103/001-4/2510-000002; W. U. KG 101
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Department of the Navy Washington, D. C. 20361		12. REPORT DATE 25 March 1974 13. NUMBER OF PAGES 26
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Catapult Start of Run
Catapult Release
Fatigue
Service Life

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A laboratory fatigue test will be performed on an E-1 airframe to determine whether the airframe will sustain the effects of 3,000 catapult launches without structural failure.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(*When Data Entered*)

SECURITY CLASSIFICATION OF THIS PAGE(*When Data Entered*)

INTRODUCTION

The majority of E-1/C-1 airplanes now in service have exceeded or are approaching their authorized 750 catapult launches. Furthermore, current projected operational requirements for these airplanes necessitates their possessing a capability for sustaining 3,000 catapult launches. In view of the above, the catapult structure in the fuselage is presently being reinforced to increase its strength to sustain the additional required catapult launches. These airplanes, with or without reinforced catapult keels, have never been tested to establish their actual catapult launch fatigue lives under service conditions. The fuselage structure of these two model type airplanes is identical in the critical region, but the gross weight of the E-1 is 25% higher than that of the C-1. Therefore, if a modified E-1 airframe is subjected to a simulated catapult launch fatigue test, the results will safely be applicable to the C-1 airplane also.

The objective of this program is to ascertain the structural capacity of the E-1/C-1 airplanes with reinforced catapult keels to sustain the cumulative effects of repeated catapult launches and to safely extend the current usage limits of these airplanes to 3,000 launch cycles.

The objective of this program plan is to present all pertinent engineering data required to set up and perform catapult and hold-back fatigue tests on the E-1 model airplane.

SYMBOLS

All symbols used herein are as defined below and in the test of this report:

FS -- Fuselage Station
FRL - Fuselage Reference Line
LL -- Limit Load = 2/3 Design Ultimate Load
R_e -- Resultant Load

SIGN CONVENTION

The following sign convention is used:

Distances and forces are positive when they are up, aft, and to the left with respect to the reference axes (See Figure 1).

Positive bending moments produce compression in the top surface and left side of the fuselage.

Positive vertical shear results when the positive vertical loads are summed from a station of greater magnitude to one of lesser magnitude.

Positive lateral shear results when the positive lateral loads are summed from a station of greater magnitude to one of lesser magnitude.

Positive torsion about the FRL results when a station of higher number rotates clockwise in relation to a station of lower number when viewed from aft.

REFERENCE AXES (See Figure 1)

X - axis: Lies in the plane of symmetry and is coincident with the FRL

Y - axis: Perpendicular to the plane of symmetry through the X axis at FS zero.

Z - axis: Perpendicular to the X-Y plane through the intersection of the X and Y axes.

BASIC DATA (References (a) and (b))

Catapulting design gross weight-----------------26,600 pounds

Catapulting test condition--------------Grumman Aerospace Corp. (GAC) Condition 7B, Catapult Start-of-Run

Catapult hold-back test condition-------GAC Condition 7A, Catapulting Release

TEST PROGRAM

The test program will consist of a fatigue test for the catapult start-of-run condition followed by a fatigue test for the catapulting release condition. The catapulting release condition occurs upon fracture of the hold-back link. Each test will include a scatter factor of two; i.e., satisfactory completion of 6,000 catapult launch simulations are required to demonstrate a service fatigue life of 3,000 catapult launches.

The test article will be the E-1B airplane, serial number 147236; GAC number 35. The history of this airplane, as of 11 September 1972, when it was made available to the NAVAIRDEVCEN for test, is as follows:

Age-----------------------149 months

Total flight time----------4,776.7 hours

Number of flights----------780

Number of arrestments------788

Number of catapults--------619*

* The number of catapults (not a log book entry) was determined by using the Naval Weapons Laboratory - Dahlgren, Va., Naval Aircraft usage tape data. The February 1973 data tape indicates the following:

Number of E-1B Aircraft	60
Total flight hours	341,394
Number of arrestments	57,178
Shore Arr. since 1/69	296
Ship Arr. since 8/70	7,545
Number of months	9,006
Shore Cats. since 8/70	215
Ship Cats. since 8/70	5,933

Based on this data, it can be determined that the E-1B aircraft experiences 0.786 catapults per each arrestment. Therefore, the assumed number of catapults for the test article is:

788 arrestments X 0.786 cats/arr = 619 catapults

For the purpose of this test program, and as a prototype for the E-1/C-1 model airplanes, the catapult keel of the E-1B 147236 was reinforced by the NAVAIREWORKFAC Quonset Point. This reinforcement is detailed in AFC #92 and in reference (c). A stress analysis and fatigue life analysis of the reinforced catapult keel is given in reference (d). The fatigue life analysis indicates a predicted life of 3900 catapults (counting from original delivery of the aircraft) for the reinforced E-1B catapult keel, provided the reinforcement is incorporated at or prior to 1600 catapults.

TEST METHOD

The test specimen will be supported at three points. The two dummy main landing gear will react vertical, axial, and lateral loads. The third support point will react vertical loads only. This third support will be, for the start-of-run condition a dummy tail gear, and for the catapult release condition, a dummy catapult hook. The airplane will be positioned so that the FRL is parallel to and 120 inches above the floor and the plane of symmetry is perpendicular to the floor.

Loading of the specimen will be accomplished by an electro-hydraulic, servo controlled, closed loop loading system. The tare weight of the test specimen will be reacted by the support points. The catapult hook and arresting hook will be removed and replaced by dummy fittings.

TEST LOADS

The E-1 aircraft was designed for use with hydraulic powered shipboard catapults. The launching conditions design curves found in reference (a) relate to that design concept. However, the aircraft-carriers now in service have the newer steam powered catapults rather than the hydraulic powered ones. Due to the use of these steam catapults, which provide a smoother, more uniform catapulting stroke than did the hydraulic catapults, the E-1 catapulting loads have changed. The new catapult drag load is determined as follows:

For C11-1 steam catapult; dry conditions; W-O-D (Wind-Over-Deck) = 0 kts.; 100 kts. end speed; and single engine operation.

Design gross weight = 26,600 lbs. (References (a) and (b))

With 90° day and W-O-D = 0 kts; (Reference (e))

Effective gross weight = 27,400 lbs.

Effective W-O-D = -3 kts. (1 $^{kt}/_{10°F}$ above 59°F)

Receiver pressure = 224 psi

Therefore, using reference (f),

Mean tow load parallel to deck = 82,000 lbs. limit

Maximum tow load parallel to deck = 88,000 lbs. limit

(Design tow load parallel to deck = 95,449 lbs. limit; reference (b))

Using the equations of reference (b) the catapult limit loads are:

Ground Axis	Fuselage Reference Axis
D =-88,000#/-82,000#	X = -82,426#/-76,806#
V =-39,160#/-36,490#	Z = -49,837#/-46,439#
S = 15,592#/ 14,529#	Y = 15,592#/ 14,529#

The above maximum horizontal (D or X) and maximum vertical (V or Z) loads will be used as the test catapult limit loads. The side load (S or Y) however is further modified as follows:

Design side load = 16,911#
GAC proposed side load = 5,900#

The GAC proposed side load is based on reference (g) and the assumption that the newer catapults produce lower side loads. Though exception is not taken to the GAC approach of defining a new side load it is considered that some conservatism is required to allow for any unusual conditions or major changes in mission. A test catapulting side load equal to 11,400# limit has

therefore been chosen. This side load was developed, with NAVAIRSYSCOM concurrence, by averaging the GAC design side load and the GAC proposed side load.

The magnitudes of the discrete ultimate test loads are listed in Table I for the catapult start of run condition and in Table II for the catapult release condition.

The design and test curves are as shown in Figures 2 through 13. The differences between the design and test curves are due to the use of the new catapulting loads as derived above. The balance diagram showing the locations of the applied loads and reactions, numbered to agree with Tables I and II, are shown in Figures 14 and 15.

TEST SPECTRUM

The test spectra are as shown in Tables III and IV. The spectrum for catapult release is as specified in reference (h). The spectrum for catapult start-of-run is altered from that shown in reference (h) as follows:

Reference (h) spectrum	Current Test Spectrum
(a) Apply limit tow load	(a) Apply mean tow load 90% of the time/maximum tow load 10% of the time.
(b) While maintaining forward component of tow load, vary direction of load from one side to the other, repeated twice	(b) While maintaining forward component of the mean/maximum tow load, vary direction of load from one side to the other, once to each side
(c) Reduce load to zero	(c) Reduce load to zero

This spectrum alteration was directed by NAVAIRSYSCOM and is based on aircraft usage information.

As mentioned previously, to demonstrate the capability to withstand the effects of 3,000 launches in service, a scatter factor of 2 will be incorporated and 6,000 catapults (6,000 applications of the start-of-run condition followed by 6,000 applications of the release condition) will be applied in the laboratory test.

REFERENCES

(a) GAC Report No. 3639.01C, Determination of Conditions for Catapulting Static Tests, Model WF-2, 3 Dec 1958.

(b) GAC Report No. 3603.3C, Ground Loads, Model WF-2, Rev. 20 Aug 1957.

(c) GAC Drawing No. 117-201B, Catapult Hook Reinforcing Strap for Extended Service Life - Model E-1B, 23 Feb 1972.

(d) GAC Report No. 00P-72-1, Analytical Evaluation of Service Life for the S-2, E-1B, C-1A Aircraft - Phase V, 31 Mar 1972.

(e) A/C Launch Bulletin No. 6-52D.

(f) LTV Report 2-53420/6R-2259, Appendix C, Determination of the Characteristic Non-Dimensional Load Stroke Diagram for Ship Based and Shore Based Catapult and Arresting Gear From Analysis of Airplane and Dead Load Test Data.

(g) GAC Report 3625.9, Carrier Suitability Trials of X52F-1.

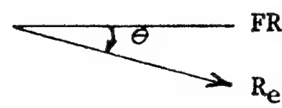
(h) MIL-A-8867 (ASG), Military Specification - Airplane Strength and Rigidity Ground Tests, 18 May 1960.

TABLE I - TEST LOADS - CATAPULT START OF RUN - HOOK LOAD LEFT

Load Point	Maximum Applied Levels					
	Location, Inches			Ultimate Loads, lbs.		
	X	Y	Z	X	Y	Z
1. Arresting Hook	449.513	0	-6.000	20,000	0	-3,400
2. Radome drag ftg	266,761	0	49.904	10,000	0	3,800
3. Wing, left	231.816	51.25	38.140	5,000	0	0
right	231.816	-51.25	38.140	5,000	0	0
4. Wing, left	231.816	60.75	38.140	5,000	0	0
right	231.816	-60.75	38.140	5,000	0	0
5. Engine, left	210.000	110.00	23.000	24,000	0	0
right	210.000	-110.00	23.000	24,000	0	0
6. Catapult hook	132.000	0	-35.250	-123,636	17,100	-74,786
7. Nose bulkhead	46.000	0	0	10,000	0	0
	Reaction Loads					
8. Holdback ftg	475.250	0	-13.920	0	0	450
9. Main gear, left	220.563	102.395	-30.000	423	-8,550	36,529
right	220.563	-102.395	-30.000	15,213	-8,550	37,407

Notes: 1. The X and Z loads at load points 1, 2, & 6 are applied as the following resultant loads at the following angles:

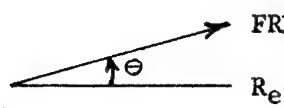
Load point 1.



$\theta = 9^\circ\ 38.9'$

$R_e = 20{,}287\#$

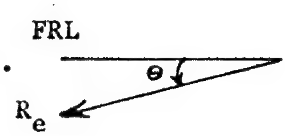
Load point 2.



$\theta = 20^\circ\ 48.4'$

$R_e = 10{,}698\#$

Load point 6.



$\theta = 31^\circ\ 10.2'$

$R_e = 144{,}495\#$

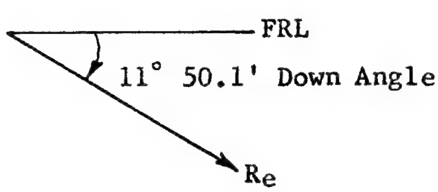
2. For the hook load right condition the side loads (Y) at points 6 and 9 reverse direction and the axial loads (X) and vertical loads (Z) at point 9 interchange.

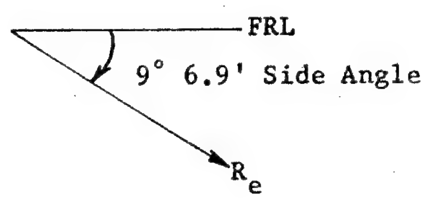
TABLE II - TEST LOADS - CATAPULT RELEASE - HOOK LOAD LEFT

Load Point	Applied Loads					
	Location, Inches			Ultimate Loads, lbs.		
	X	Y	Z	X	Y	Z
1. Holdback ftg.	475.250	0	-13.92	41,850	5,205	-7,005
	Reaction Loads					
2. Main gear, left	220.563	102.395	-30.00	-14,452	-2,603	17,783
right	220.563	-102.395	-30.00	-27,398	-2,603	16,965
3. Catapult hook	132.000	0	-35.25	0	0	-27,743

Notes: 1. Catapult Release is holdback link fracture simulated by use of a quick-release mechanism.

2. The loads at load point 1 are applied as a resultant load R_e = 42,750# at the following angles:





3. For the hook load right condition the side loads (Y) at points 1 & 2 reverse direction and the axial loads (X) and vertical loads (Z) at point 2 interchange.

TABLE III - TEST SPECTRUM - CATAPULT START OF RUN

The test spectrum to be used for the E-1 catapult start-of-run fatigue test is as follows:

1. Apply 93.18% LL for all X and Z loads.

2. While holding the above, apply the side load (load type Y) in the following order:

   0% LL

   93.18% LL to the left

   0% LL

   93.18% LL to the right

   0% LL

3. Reduce the loads of step 1 to zero.

4. Repeat steps 1 through 3 (one application of the catapult condition) nine (9) times.

5. Repeat steps 1 through 3 using 100% LL in lieu of 93.18% LL one (1) time.

6. Repeat steps 1 through 5 (ten applications of the catapult condition) 600 times.

TABLE IV - TEST SPECTRUM - CATAPULT RELEASE

The test spectrum to be used for the E-1 catapult-release fatigue test is as follows:

1. Apply 100% LL for all loads. Holdback resultant load displaced to the left.

2. Reduce the loads of step 1 to zero by actuating a quick-release mechanism to simulate link fracture.

3. Repeat steps 1 and 2 for 250 times.

4. Repeat steps 1 through 3 with the holdback resultant load displaced to the right.

5. Repeat steps 1 through 4 (500 applications of the catapult release condition) 12 times.

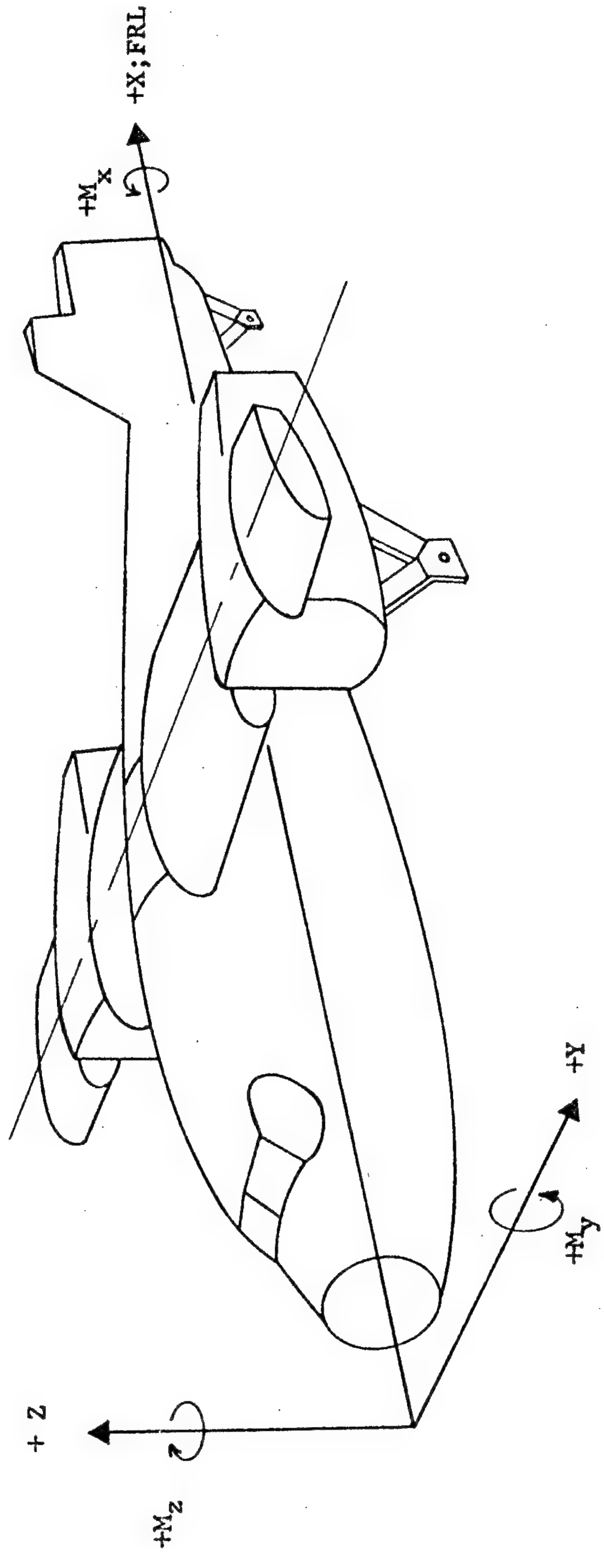


Figure 1. Reference Axes and Sign Convention; E-1 Catapult Fatigue Test

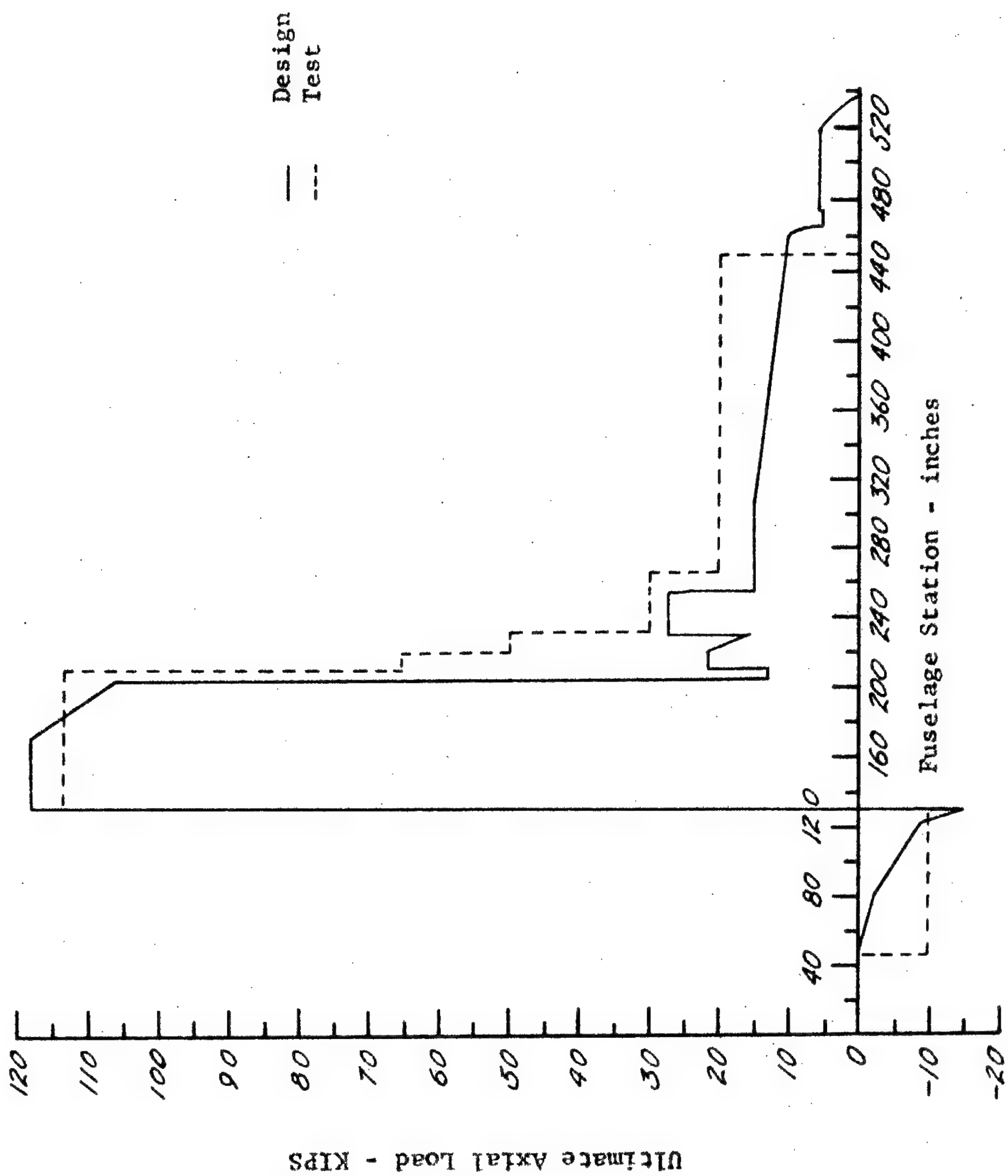


Figure 2. Axial Load Distribution, Catapult Start of Run Condition

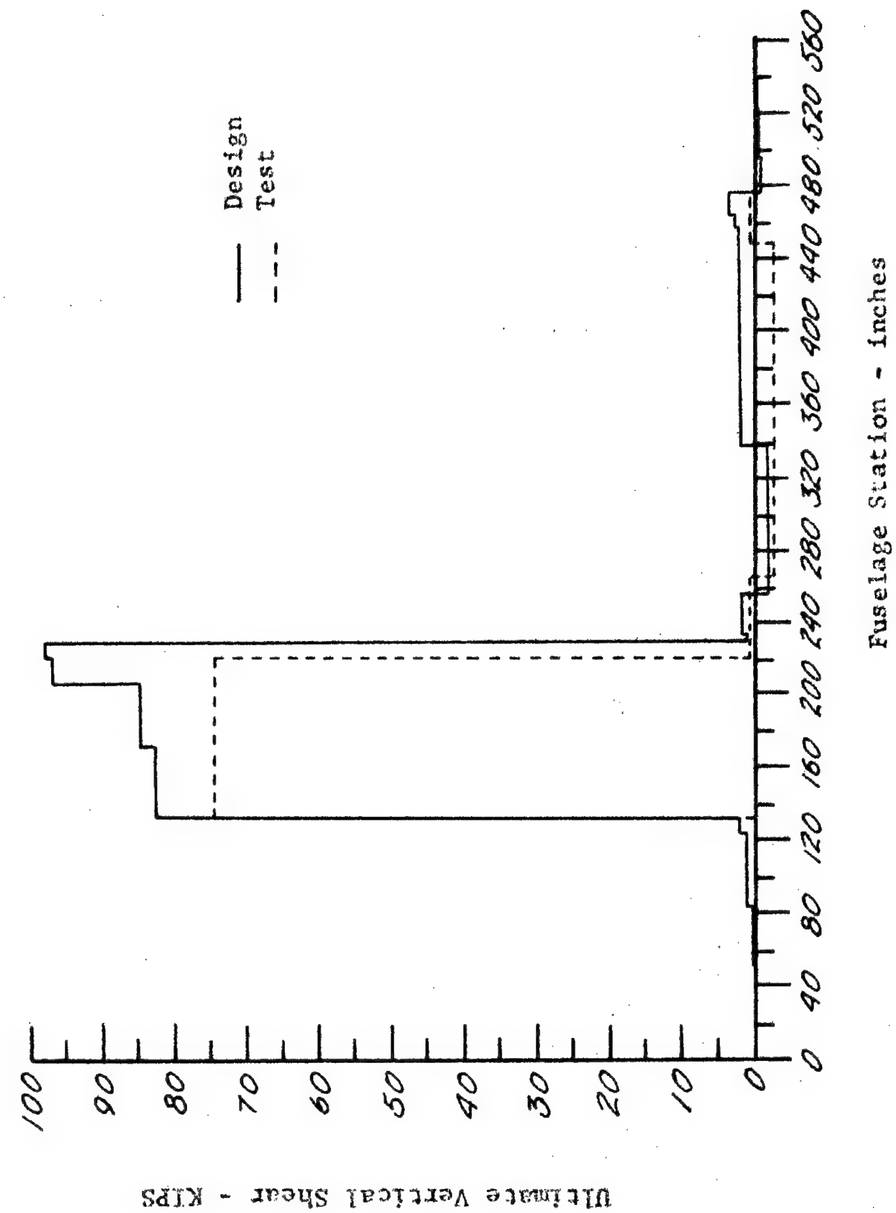


Figure 3. Vertical Shear Distribution, Catapult Start of Run Condition

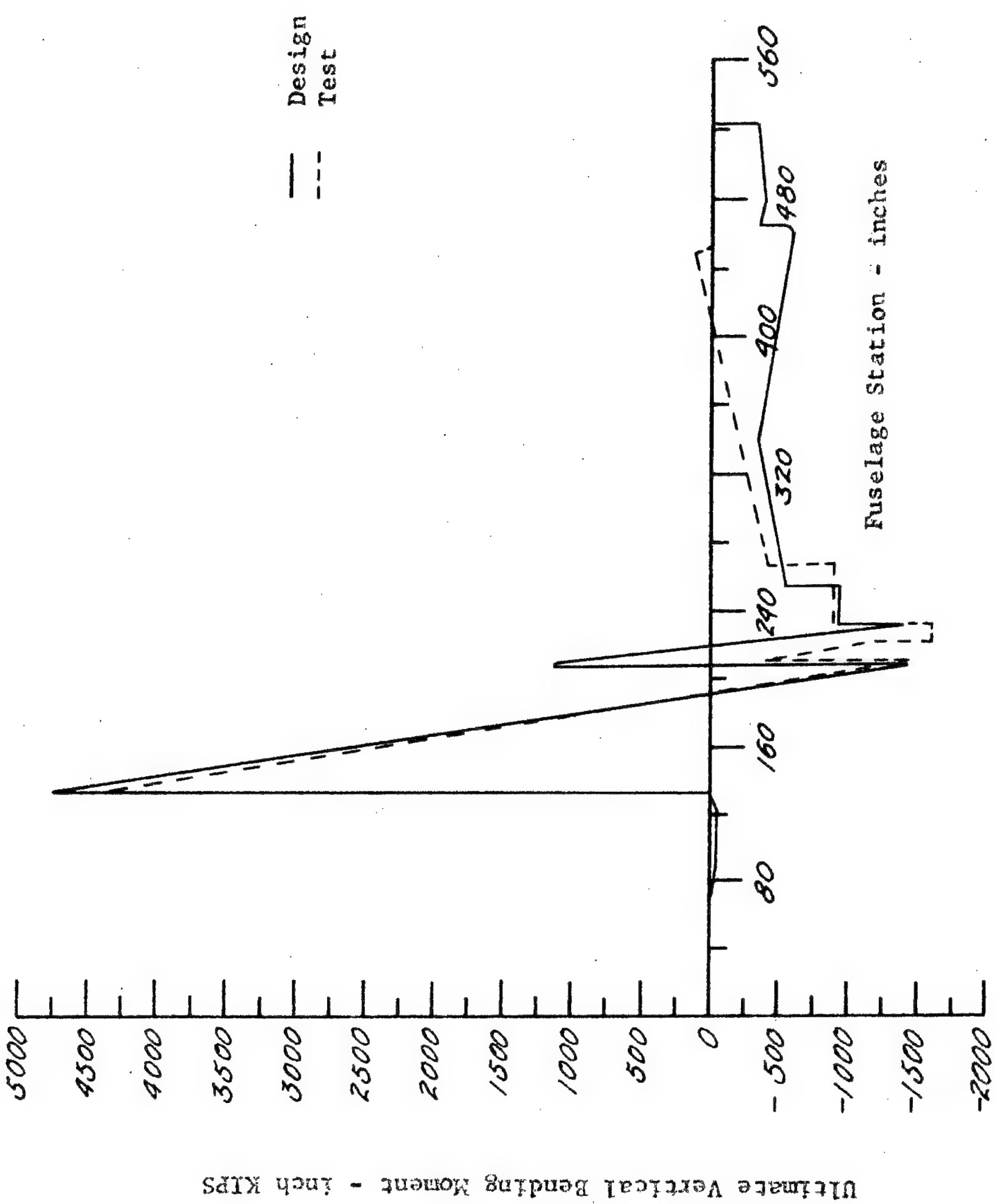


Figure 4. Vertical Bending Moment Distribution, Catapult Start of Run Condition

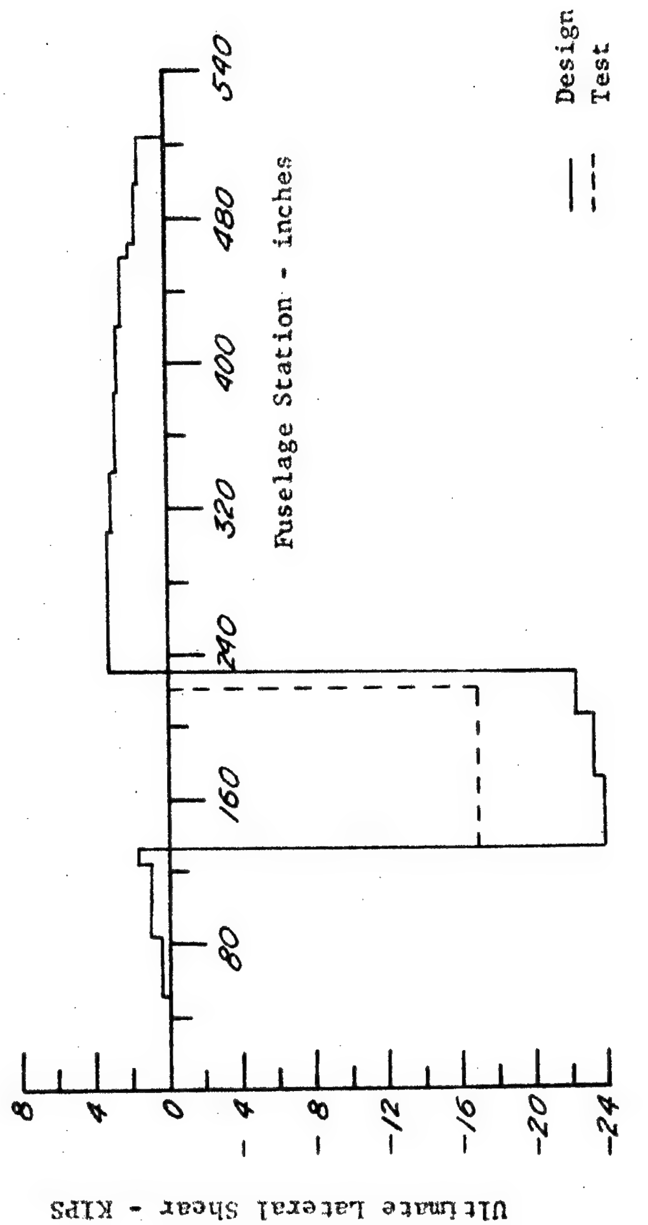


Figure 5. Lateral Shear Distribution, Catapult Start of Run Condition

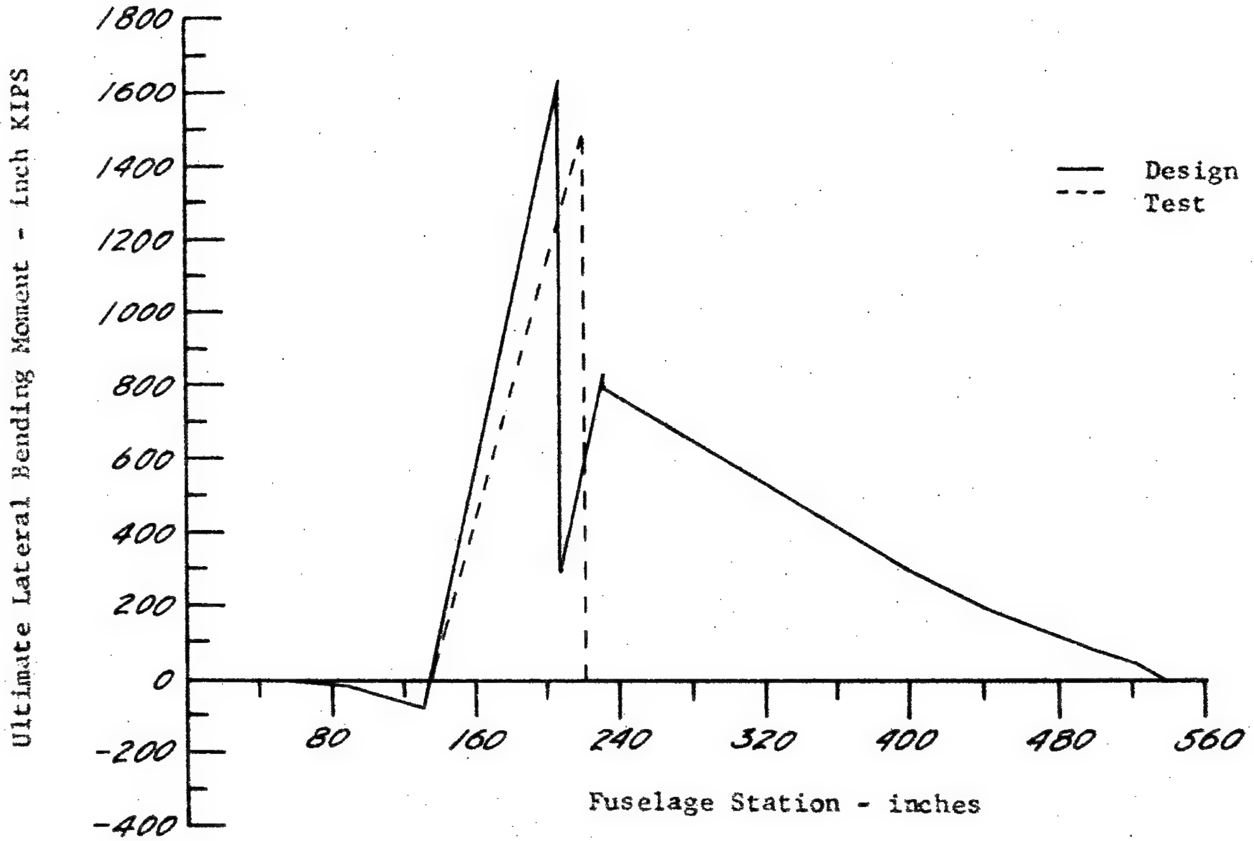


Figure 6. Lateral Bending Moment Distribution, Catapult Start of Run Condition

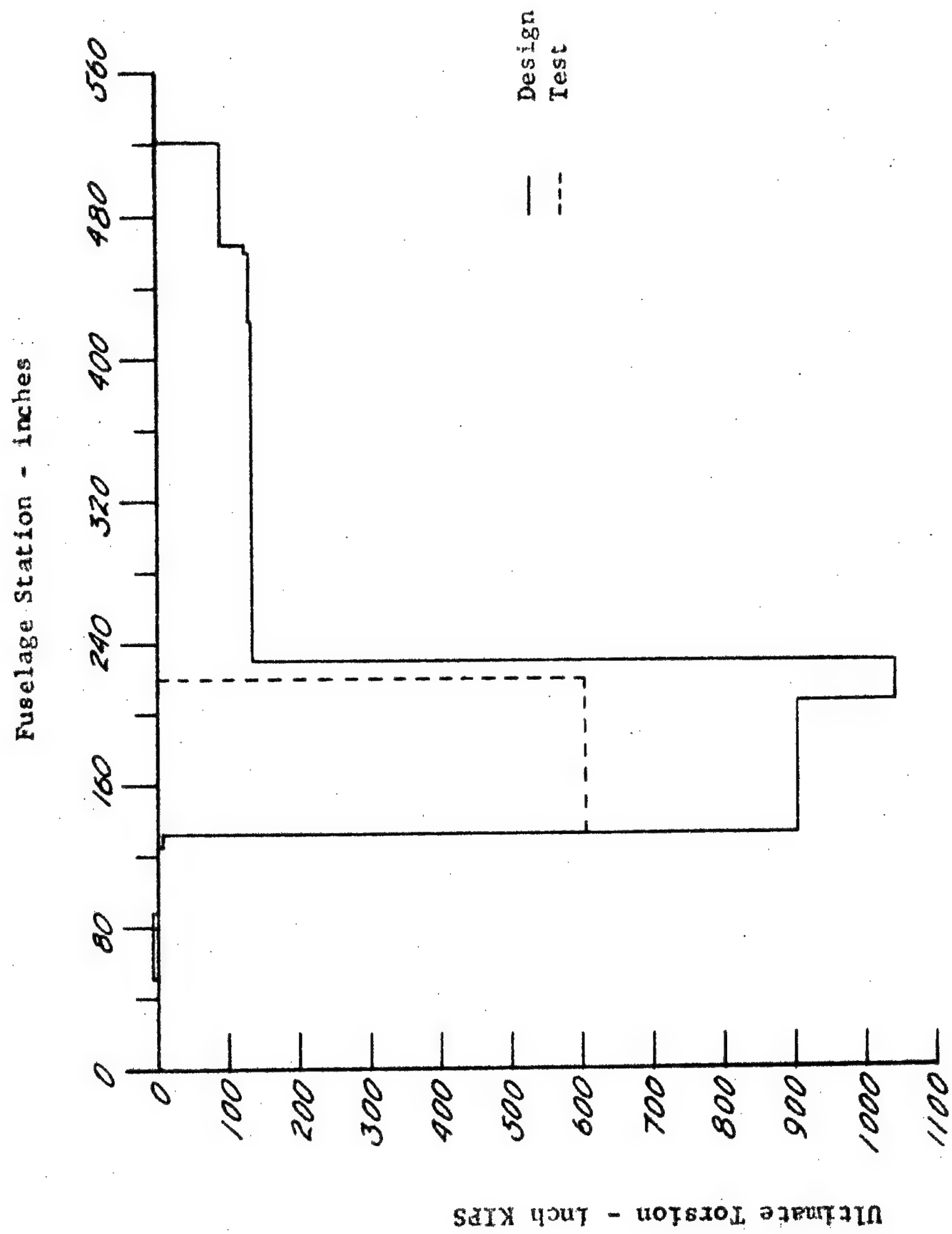


Figure 7. Torsional Distribution, Catapult Start of Run Condition

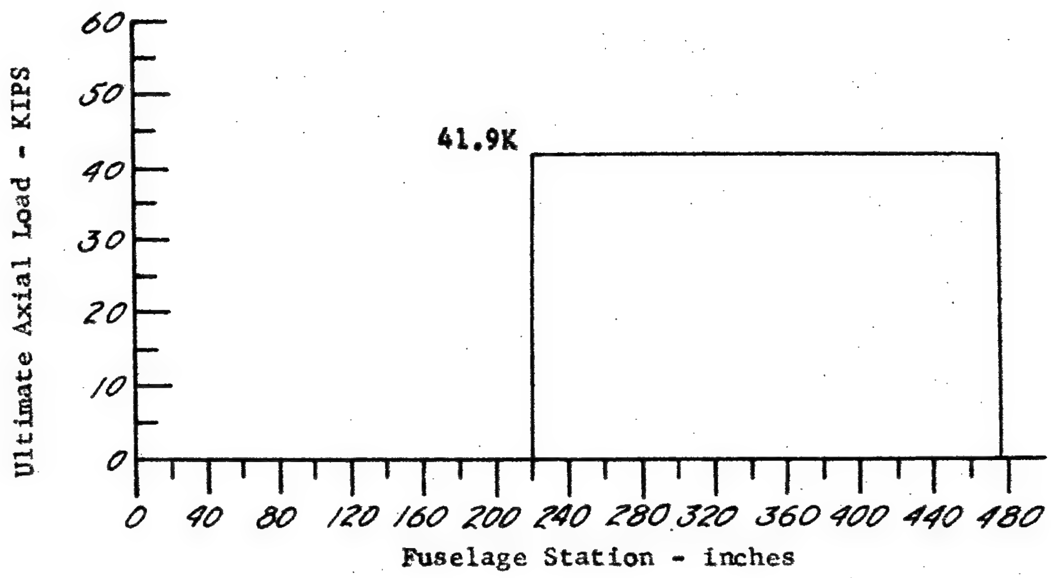


Figure 8. Axial Load Distribution, Catapult Release Condition

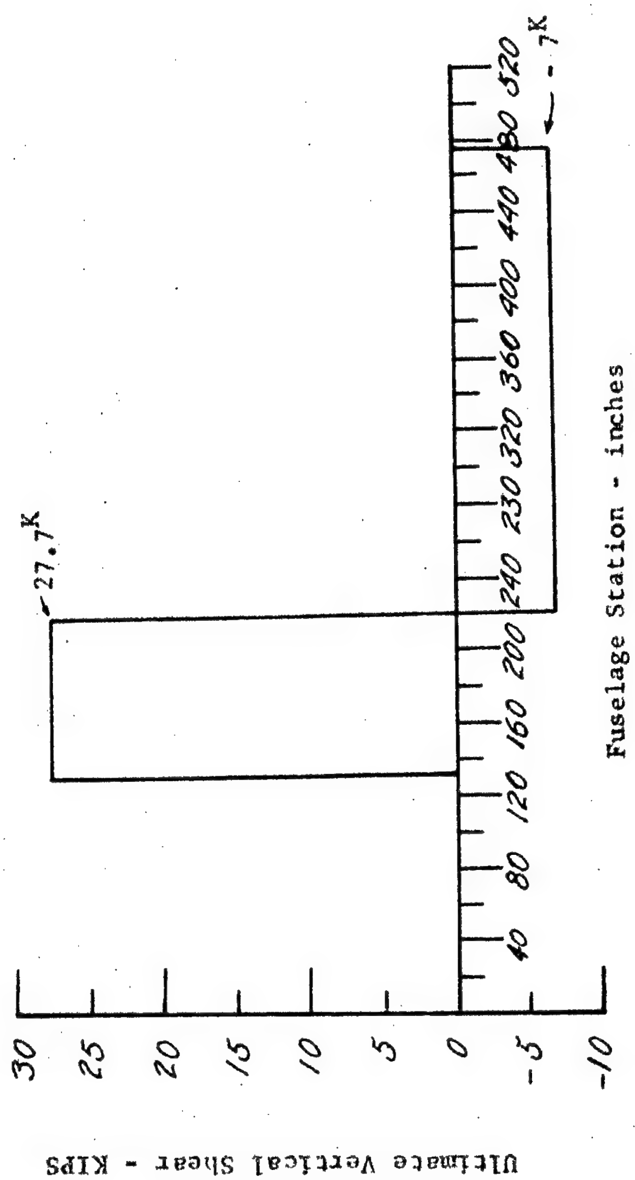


Figure 9. Vertical Shear Distribution, Catapult Release Condition

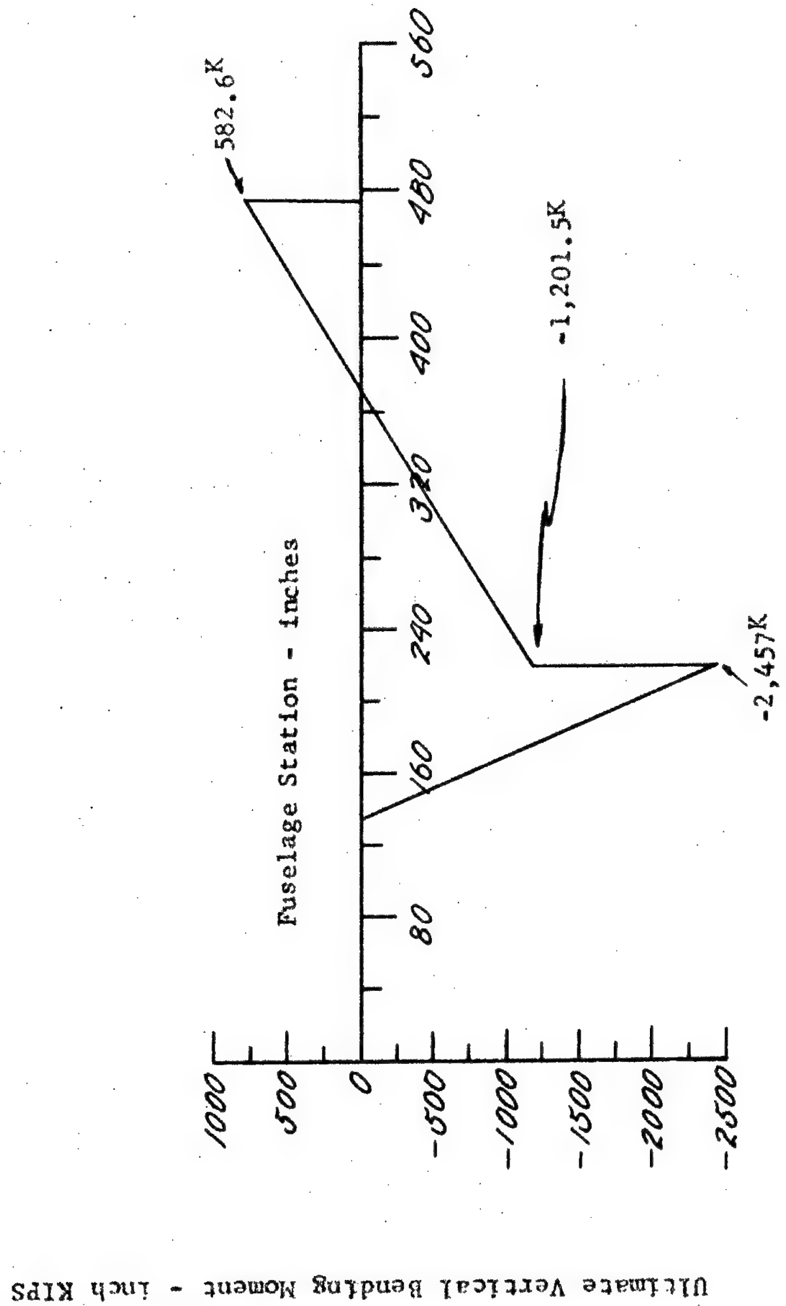


Figure 10. Vertical Bending Moment Distribution, Catapult Release Condition

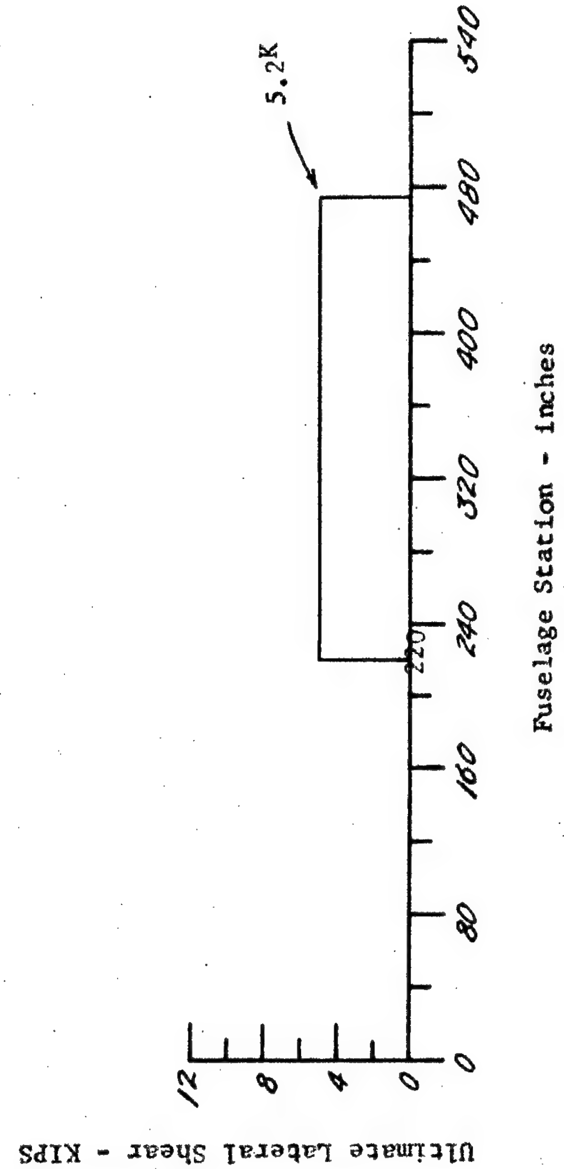


Figure 11. Lateral Shear Distribution, Catapult Release Condition

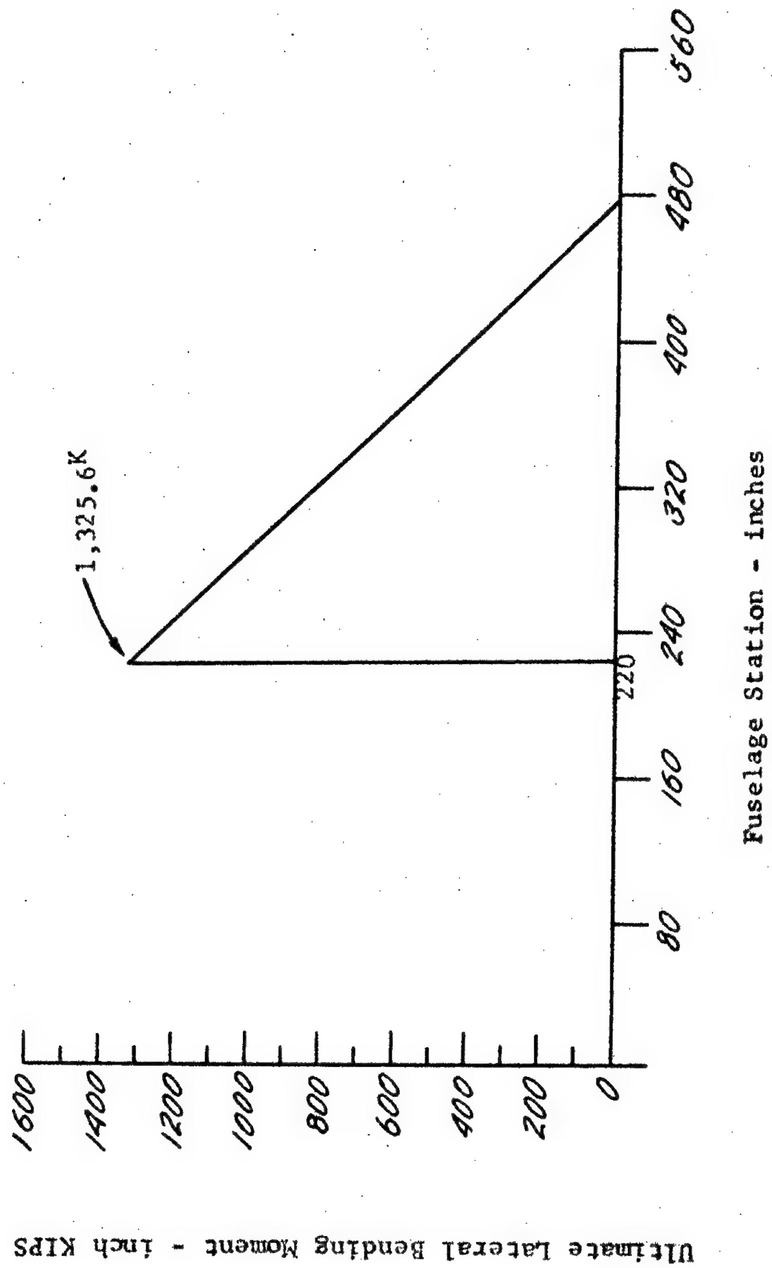


Figure 12. Lateral Bending Moment Distribution, Catapult Release Condition

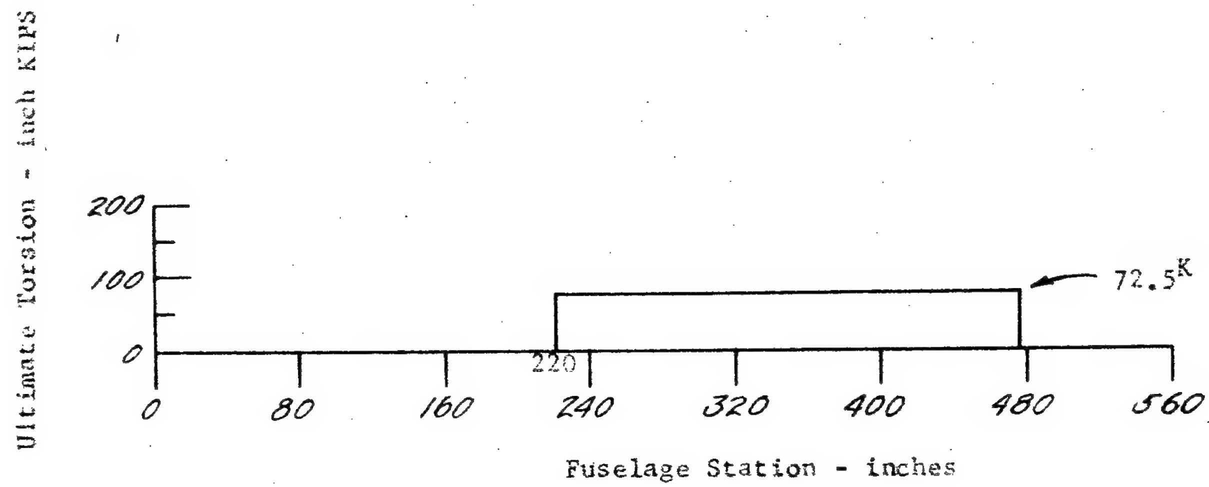
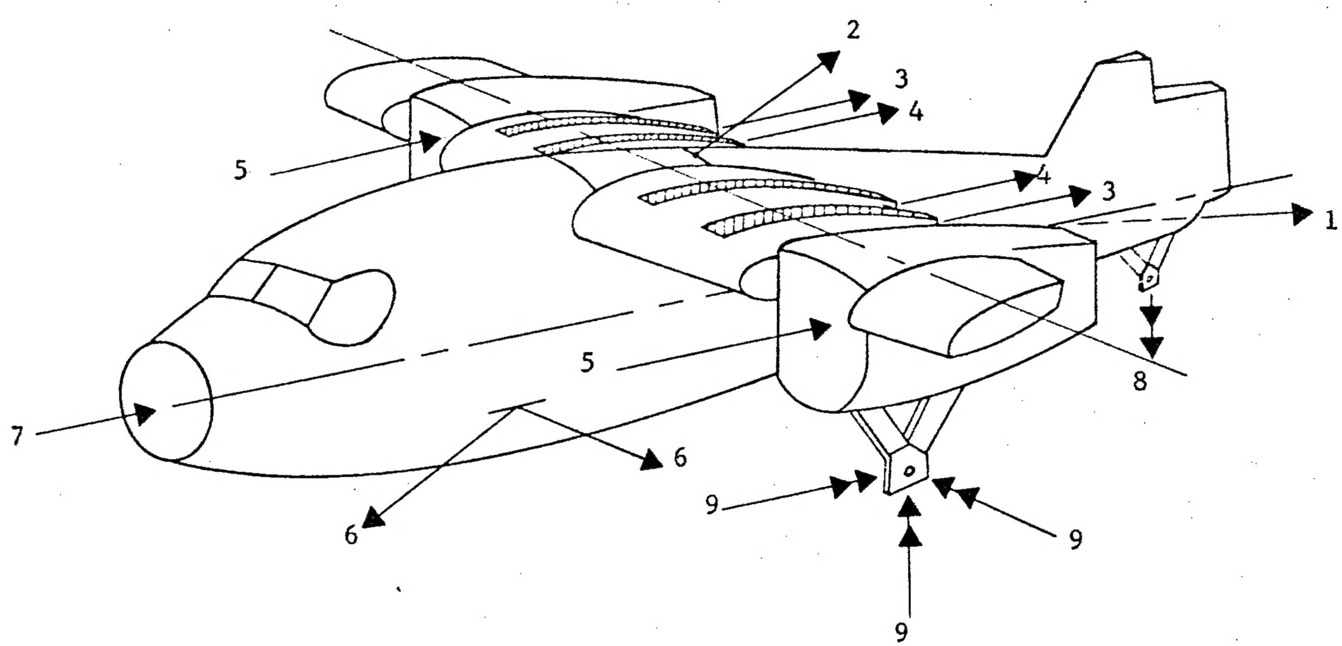


Figure 13. Torsional Distribution, Catapult Release Condition

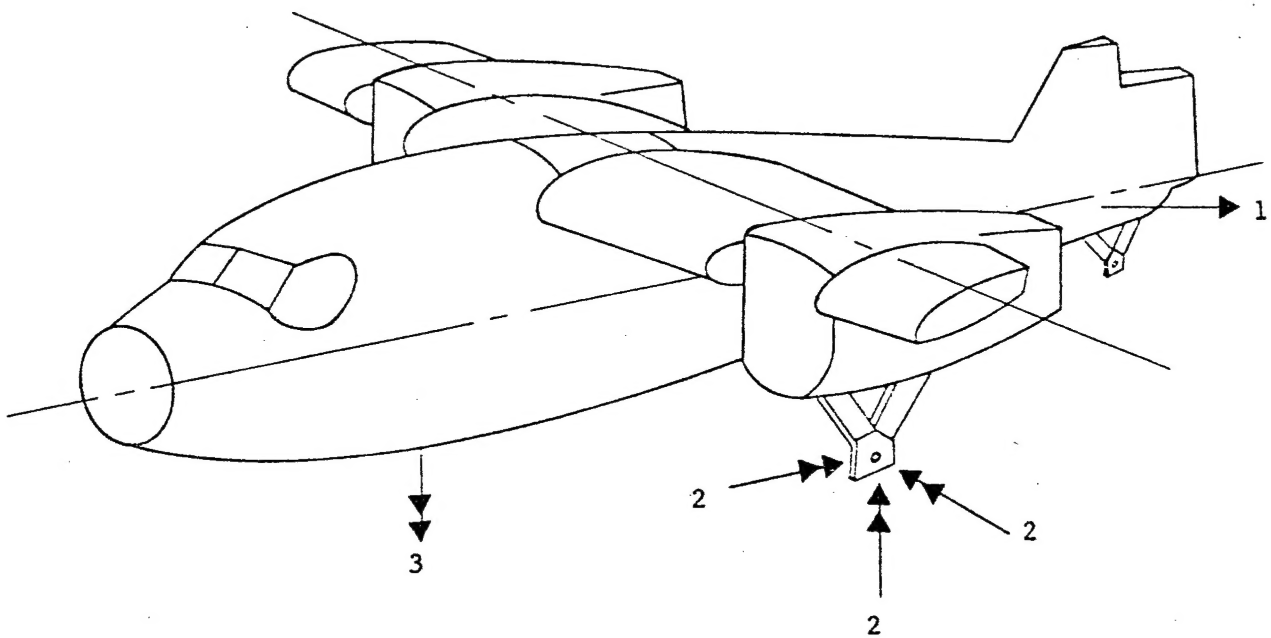


Notes: 1. The numbers correspond to the load point numbers of Table I.

2. ——→ = applied load.

3. ——→→ = reaction load.

Figure 14. Balance Diagram; E-1 Catapult Fatigue Test, Catapult Start of Run Condition



Notes: 1. The numbers correspond to the load point numbers of Table II.

2. ———► = applied load.

3. ———►► = reaction load.

Figure 15. Balance Diagram; E-1 Catapult Fatigue Test, Catapult Release Condition

DISTRIBUTION LIST

REPORT NO. NADC-74058-30

AIRTASK NO. A510-5103/001-4/2510-000002
Work Unit No. KG 101

	No. of Copies
NAVAIRSYSCOM,(AIR-50174)	8
(2 for retention)	
(1 for AIR-410)	
(1 for AIR-510)	
(1 for AIR-530)	
(3 for AIR-53022)	
NAVAIREWORKFAC, NAS, Jacksonville, Fla. (Code 300)	2
" Alameda, Calif. "	1
" Cherry Point, N. C. "	1
" Norfolk, Va. "	1
" North Island, San Diego, Calif.	1
" Pensacola, Fla. (Code 300)	1
NAVAIRSYSCOMREPLANT, NAS, Norfolk, Va.	1
NAVAIRSYSCOMREPAC, NAS, San Diego, Calif.	1
NAVAIRTESTCEN, Patuxent River, Md.	1
U.S. Naval Academy, Annapolis, Md.	1
Grumman Aerospace Corp. (One for retention, one for Mr. J. Diglio)	2
DDC	12
NAVAIRDEVCEN, Warminster, Pennsylvania 18974	30

(3 for 813) (1 for 301)
(3 for 30023) (1 for 302)
(1 for 03) (1 for 303)
(1 for 20) (1 for 304)
(1 for 40) (1 for 305)
(1 for 50) (15 for 3031)

740024IA